INSTITUTE OF MACHINE AND INDUSTRIAL DESIGN

FME

Faculty of Mechanical Engineering
Brno University of Technology

Review of Doctoral Thesis

1. PhD candidate
Risha Rufaqua, MSc, MBA / risha.rufaqua@vut.cz
2. Name of PhD programme
Design and Process Engineering (Mechanical Engineering Design)
3. Title of PhD thesis
The Biochemical Process of Lubricant Film Formation Inside Hip Joint Replacement

4. Principal supervisor
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7. Overview of the scope of PhD thesis[1]
Evaluate: **Very Good**
Justification for evaluation: Arthroplasty is a surgical procedure consisting in the physical replacement of an unhealthy natural human synovial joint with an artificial one. The artificial joints have to guarantee biocompatibility, fixation, mobility, load capacity, stability and minimal friction and wear of the tribo-system. The wear phenomenon in a joint is affected by several factors, like the coupled materials, the geometry of the tribopair, the roughness of the contact surfaces, the load conditions and the lubrication of the tribosystem, hence the lubricant film formation chemistry on hip implant material surfaces, with synovial fluid components, plays a key role on the tribological behaviour of artificial joints. The proposed PhD Thesis aims to investigate the synovial lubricated film formation and its chemisorption on the THR implant surfaces considering various combination of implants materials. The approach was mainly based on Raman Spectroscopic techniques and on pendulum hip simulator for the friction coefficient assessements.

8. Significance of the topic and clarity of problem statement
Evaluate: **Very Good**
Justification for evaluation: The objective and the problem statement of the investigation is clearly exposed in the framework of scientific literature. The used method is approached by introducing two different

[1] Overview of the scope of PhD thesis is a short description of objectives of PhD thesis's research and summary of main findings and scientific achievements.

studies focusing on the chemical structure of synovial film the friction coefficients measurement. A chemical analysis, including the tribological and biological properties of the SF after total joint replacement to aid in comprehension of the process, was developed. The experiments conducted in the ball-on- cup configuration considered two types of commercial ceramic hip implant pairs, namely BIOLOX®forte and BIOLOX®delta, to explore the biochemical responses of SF lubricants in the ceramic interface. The conducted researches allowed to clarify the chemistry of lubricant film formation on hip implant material surfaces while concerning on the compositional variability of the SF lubricants.

9. Knowledge of existing literature

Evaluate: **Good**

Justification for evaluation: In this Thesis the investigated topic was introduced in the framework of recent and relevant scientific literature, even if, in my opinion, this part of the Thesis lacks of a more detailed tribological knowledge on this topic. In fact, in the last years more and more hip lubrication models were proposed by several authors aimed to give a detailed modelling of the synovial film during the gait considering mixed hydrodynamic/elasto hydrodynamic lubrication modes. A complete discussion on this issue could contribute to a more complete description of the scientific framework on THR lubrication.

10. Choice of methods and technical soundness

Evaluate: **Very Good**

Justification for evaluation: The choice of the investigation methods, in my opinion, represents the main novelty of this Thesis. Raman spectroscopic technique was used to analyse the chemical structure of lubricant film by SF components, considering also fluid of different concentrations. The performed experiments allowed to obtain results on which components of SF are adsorbing chemically on hip implant material surfaces while lubricant film formation within artificial joint replacement and how the SF changing the chemical structure of its constituents due to artificial hip implant. Moreover, several different combinations of hip implant materials were considered to perform an extensive analysis of film formation, which took in to account measurement of the friction coefficient of several couples of hip implant materials, lubricated by various SF. A comparison of the frictional results in the framework of the Raman data was also performed, allowing to investigate how the frictional coefficients differing with the SF chemical change in the hip joint replacement

11. Quality, originality and significance of the results

Evaluate: **Very Good**

Justification for evaluation: The obtained results appear interesting and promising for a more detailed comprehension of the lubrication phenomena in total hip replacements. In particular in this Thesis, was introduced Raman spectroscopy in this area of research as a novel tool to investigate SF film characteristics. The proposed methodology is characterised by several advantages as non-destructiveness, contactless measurements, without the demand for sample preparation and rapidity. Raman spectroscopy allowed to observe that after the tribological test, SF spectra showed verily different fingerprints compared to before test lubricants spectra. The obtained results were discussed carefully and allowed to obtain very interesting conclusions for the several tribo-systems investigated.

12. Quality of attached papers

Evaluate: **Very Good**

Justification for evaluation: The attached papers are:1) Rufaqua R, Vrbka M, Choudhury D, Hemzal D, Křupka I, Hartl M. A systematic review on correlation between biochemical and mechanical processes of lubricant film formation in joint replacement of the last 10 years. Lubrication Science. 2019- 2) Rufaqua R, Vrbka M, Hemzal D, Choudhury D, Rebenda D, Křupka I, Hartl M. Raman analysis of chemisorbed tribo-film for metal-on-polyethylene hip joint prostheses. (Journal Biosurface and Biotribology) 3) Rufaqua R, Vrbka M, Hemzal D, Choudhury D, Rebenda D, Křupka I, Hartl M. Analysis of chemisorbed tribo-film for ceramic-on-ceramic hip joint prostheses by Raman spectroscopy. (Submitted to the Journal of Functional Biomaterials). ;31(3):85-101. Paper 1) is a Review paper published on a prestigious Journal which deals on the correlation between biochemical and mechanical processes of lubricant film formation in joint replacement of the last 10 years. Paper 2) is an interesting paper aimed to investigate the biochemical reaction during the formation of lubricant film the in case of a cobalt- chromium ball on an ultrahigh-molecular weight polyethylene, while in paper 3) was investigated the possible lubricant mechanism in ceramic-on-ceramic hip joint prostheses, biochemical reactions of the synovial fluid and the corresponding frictional coefficients.

13. Overall assessment, strengths and weaknesses (based upon the above evaluation categories 8–12)

Evaluate: **Very Good**

Justification for evaluation: The submitted Thesis was aimed to investigate the chemical behaviour, including the tribological and biological properties of the SF, after total joint replacement to aid in comprehension of the process. By using a pendulum hip simulator, the tribological behaviour of THRs were investigated also considering the friction coefficients of the contact pairs. The use of the Raman spectroscopic technique allowed to understand the chemical reactions between the SF and implant material. Cobalt-chromium ball on an UHMWPE cup arrangement was investigated to reveal the reactivity of metal against PE contact pairs. The experiments conducted in the ball-on- cup configuration also considered two types of commercial ceramic hip implant pairs, namely BIOLOX®forte and BIOLOX®delta. In my opinion the strengths of the Thesis is in the novelty of the proposed techniques (Raman Spectroscopy and Pendulum Hip Simulator) to deeply investigate the connection between chemical and tribological behaviour of synovial fluid in the lubrication of several type hip replacements. The weaknesses is the absence of any theoretical lubrication model, necessary to understand the tribological behaviour in terms of frictional behaviour of the investigated tribo-systems.

14. Questions and comments

I have one concern about the figures: The figures are usually recalled and commented on in the text….

15. Conclusion

PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.

YES

16. Date and signature

01/06/2021	

Please note

A. *Evaluate categories 7 to 13 using the following scale: unacceptable, acceptable, satisfactory, good, very good, excellent. The qualification of 'excellent' should only be given for a PhD Thesis in the top 3% of the research in your field of expertise.*
B. *E-mail the completed form to: Klara.Javorcekova@vut.cz*